Stage N° : 7

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Title
Characterizing electrical signature of magnetic skyrmions

Keywords
skyrmions, magneto-optic, magnetotransport, microfabrication

Summary
Skyrmions are chiral magnetic bubbles: magnetization follows a cycloid along a line across the skyrmion. They can appear in heavy metal/ferromagnet/oxide trilayers. Such texture results from the presence of an interfacial interaction called Dzyaloskinskii-Moriya interaction. It makes the skyrmions stable, nearly insensitive to defects and easily moveable by electrical current. They are currently very popular as they could be used as dense storage nanoscale data bits, or for magnetic logic.
Using magneto-optical microscopy, we have recently shown that a gate voltage can modulate the size and density of magnetic skyrmions in ultrathin films, ultimately leading to the realization of a skyrmion switch [1].
Electrical detection of skyrmions is necessary to develop skyrmion-based devices but is still a technological challenge. The aim of the proposed internship is to tackle this prerequisite.
The candidate will explore the electrical response of these magnetic objects while observing them. He(she) will in particular search for a signature of the skyrmion Hall effect and further test the influence of a gate voltage.
The candidate will fabricate microstructures using a clean room facility and perform magneto-optical and magnetotransport characterizations. He(she) will then participate to the result analysis and compare the data with existing models.
[1] M. Schott et al. Nano Lett., 17, 3006 (2017)

Full description of the subject
Skyrmions are chiral magnetic bubbles: their magnetic texture, or topology, is peculiar since magnetization follows a cycloid along a line across the skyrmion. They can appear in ultrathin heavy metal/ferromagnet/oxide trilayers. Such topology results from the presence of an interfacial interaction called Dzyaloskinskii-Moriya interaction (DMI). It is due to the asymmetry of the structure. This DMI makes the skyrmions stable, less sensitive to defects than usual domain walls and easily moveable by electrical current. They are currently very popular as they could be used as dense storage nanoscale data bits, with low power manipulation; they could also be used for magnetic logic with efficient operation.
Using magneto-optical microscopy, we have recently shown that the size and density of magnetic skyrmions in ultra-thin films can be modulated by a gate voltage. Finally we have even managed to create and erase skyrmions with the voltage, thus demonstrating a skyrmion switch device operation [1]. These measurements were done at room temperature with materials compatible with electronics. We have observed this skyrmion switch effect in two types of trilayers, ie. Pt/Co/AlOx and Ta/FeCoB/TaOx, where the origin and contributions of the DMI are different.
Electrical detection of skyrmions is necessary for developing spintronic devices but is still a technological challenge. The aim of the proposed internship is to tackle this prerequisite.

The candidate will explore the electrical response of these magnetic objects while observing them. For this purpose, he(she) will use a dedicated Magneto-optical Kerr effect microscope with a sample stage allowing to observe the sample and measure magnetotransport at the same time. He(she) will in particular search for a signature of the skyrmion Hall effect and further test the influence of a gate voltage on this electrical signature. For the observation through the gate, we have developed a microfabrication process with a thick oxide (50nm) and a transparent electrode, which allows applying a voltage up to ±20V over large areas (typically 500 x 50 µm2).
The candidate will thus fabricate the microstructures using the clean room facility located in the same building as Spintec (etching, atomic layer deposition, optical lithography,…) and perform the magneto-optical and magnetotransport characterizations. He(she) will then participate to the result analysis and compare the data with existing models.

[1] M. Schott et al. Nano Lett., 17, 3006 (2017)

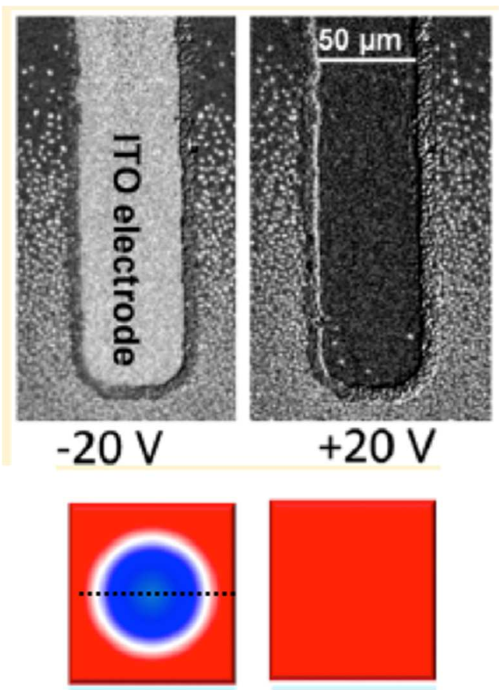
Requested skills

Master 1 condensed matter,

Possibility to follow with a PhD (Yes/No)

Yes

Figure



(Up) Kerr effect microscopy images showing evolution of skyrmion density (bright dots) under the electrode for negative (large density) and positive (very low density) applied voltages. (Down) schematics of the electrically controlled skyrmion switch: presence (-20V) or absence (+20V) of skyrmion depending on the applied gate voltage. The magnetic texture of the skyrmion along the dotted line is peculiar (see text).